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(54) **SECONDARY CONTAINMENT FOR A MAGNETIC-DRIVE CENTRIFUGAL PUMP**

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F04B 17/00 (2006.01)

(52) **U.S. Cl.** **417/420**; 417/423.11

(58) **Field of Classification Search** 417/420, 417/313, 423.11
See application file for complete search history.

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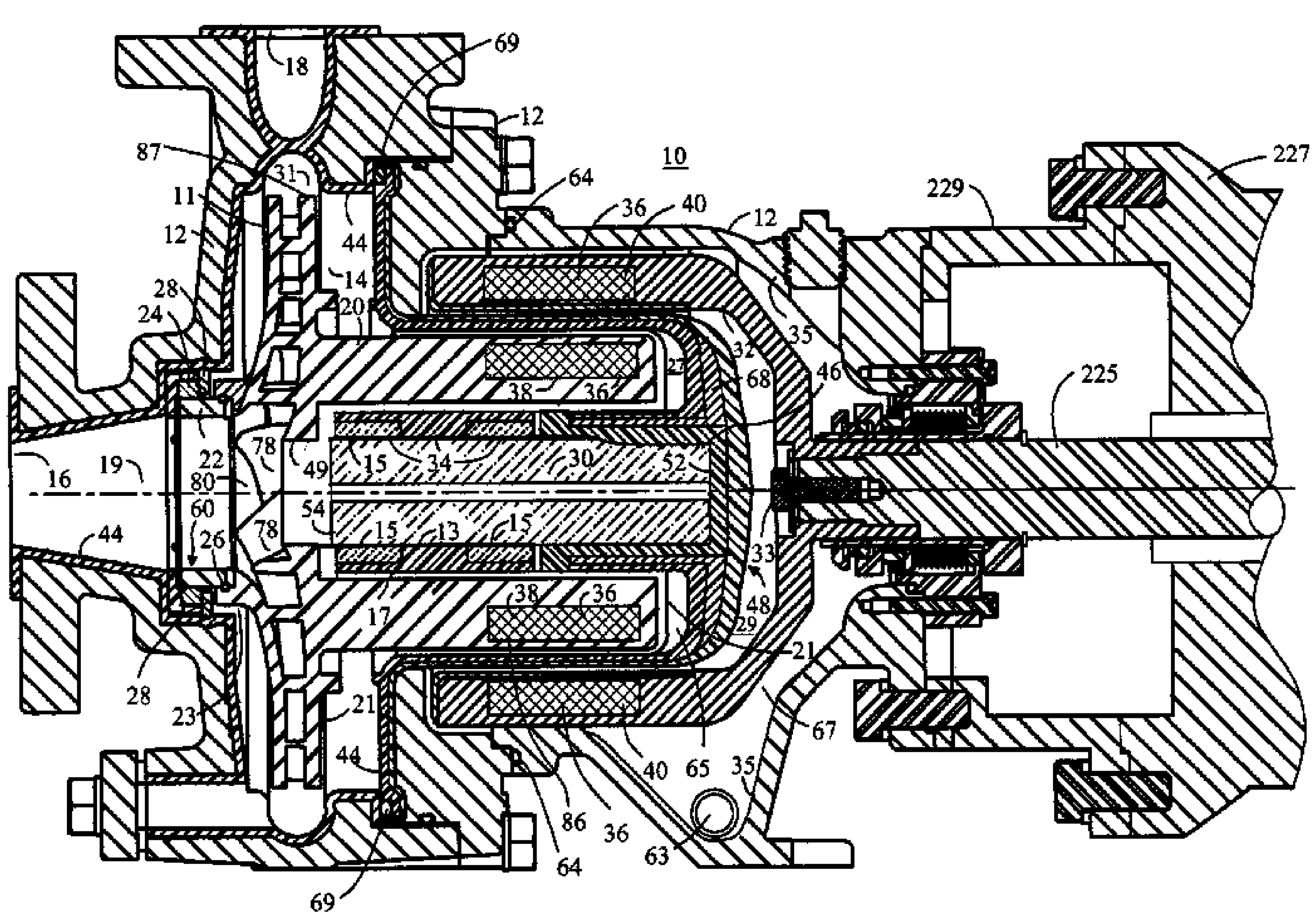
Primary Examiner—Timothy P. Solak

(57) **ABSTRACT**

A centrifugal pump includes a housing having a housing cavity, an inlet, and an outlet. A pump shaft is located within the housing cavity. A radial bearing coaxially surrounds the pump shaft. The shaft and the radial bearing are rotatable with respect to one another. An impeller is positioned to receive a fluid from the inlet and to exhaust the fluid to the outlet. The impeller has a first magnet assembly. A rotor has a second magnet assembly spaced apart from the first magnet assembly. A primary container is interposed between the impeller and the rotor. The primary container is arranged to contain a pumped fluid. A drive shaft is associated with the rotor for rotating the rotor. A secondary container contains the pumped fluid if the primary container leaks. The secondary container supports a generally dry-running seal (e.g., non-lubricated seal) associated with the drive shaft. The seal is disposed axially from the primary container and has a stationary portion and a rotating portion.

26 Claims, 7 Drawing Sheets



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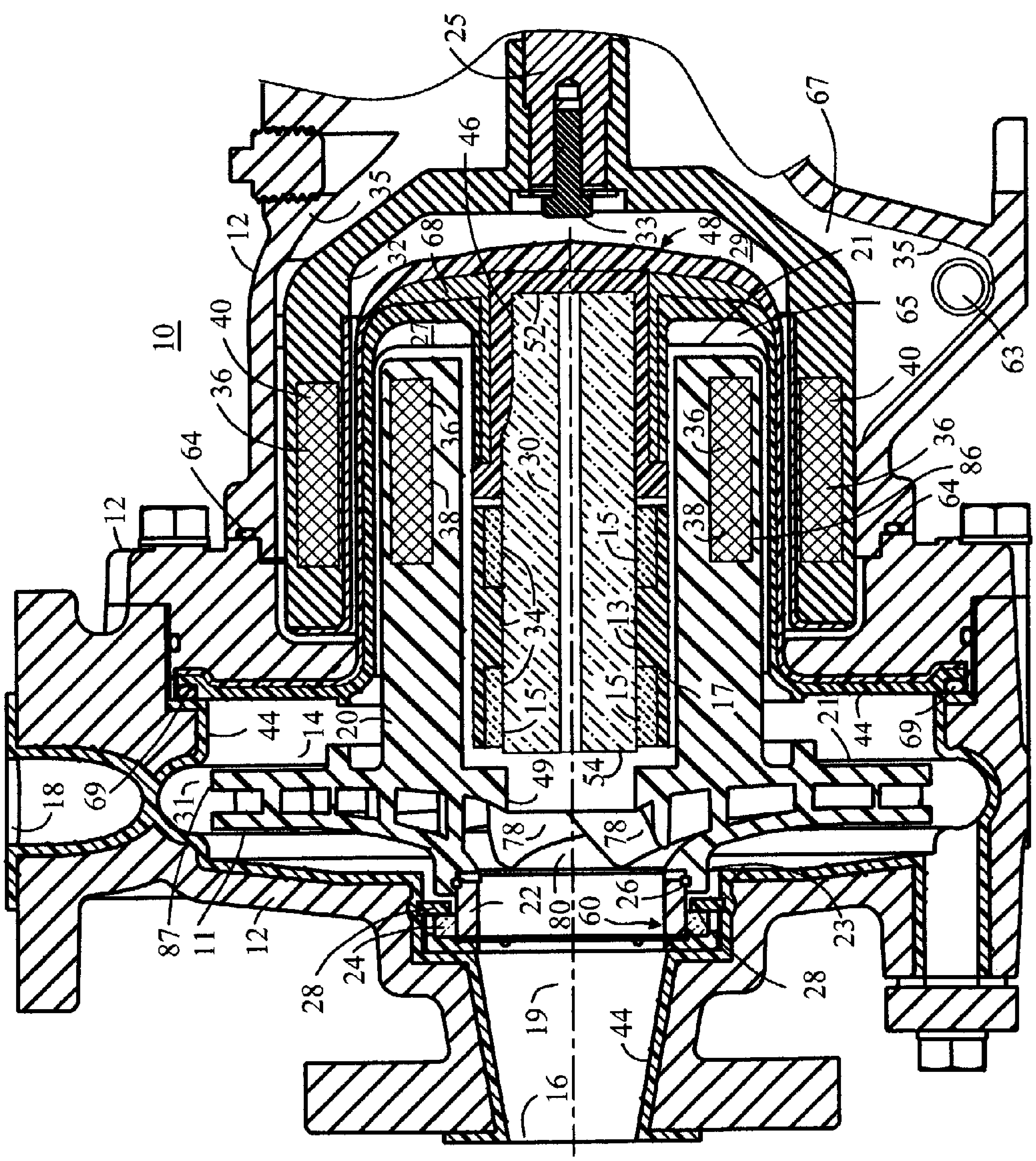
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FIG. 1A

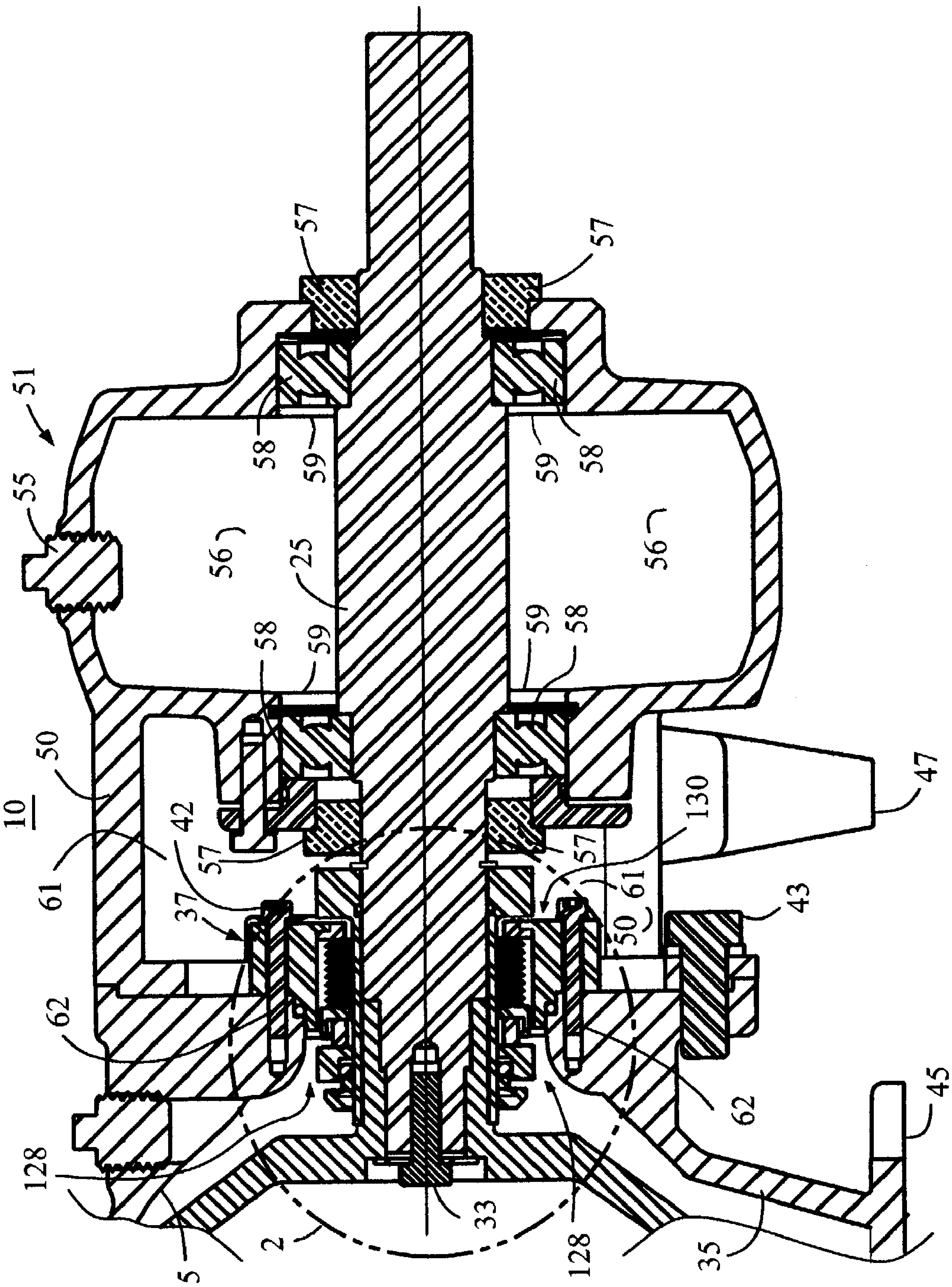

FIG. 1B

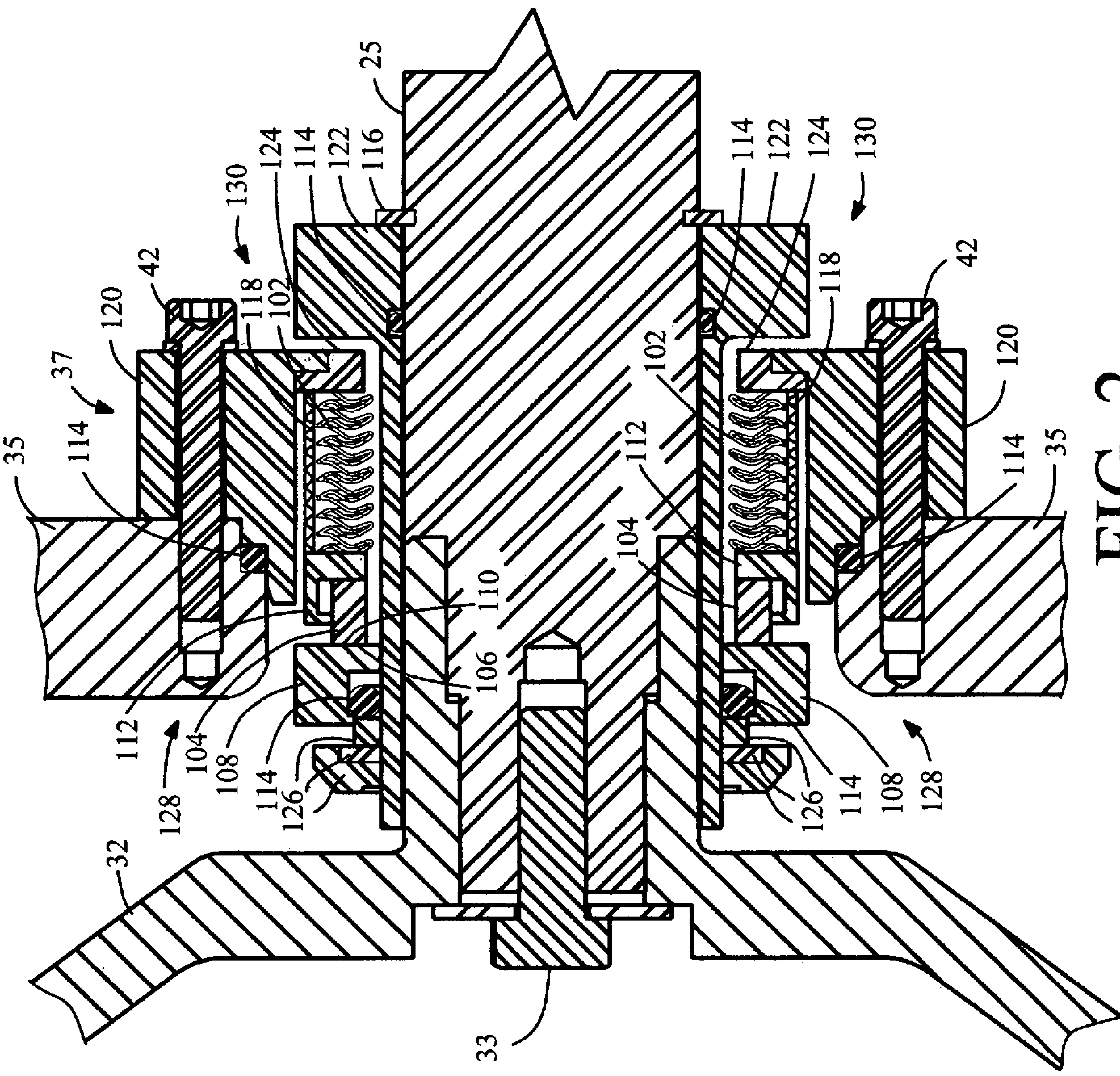
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FIG. 2

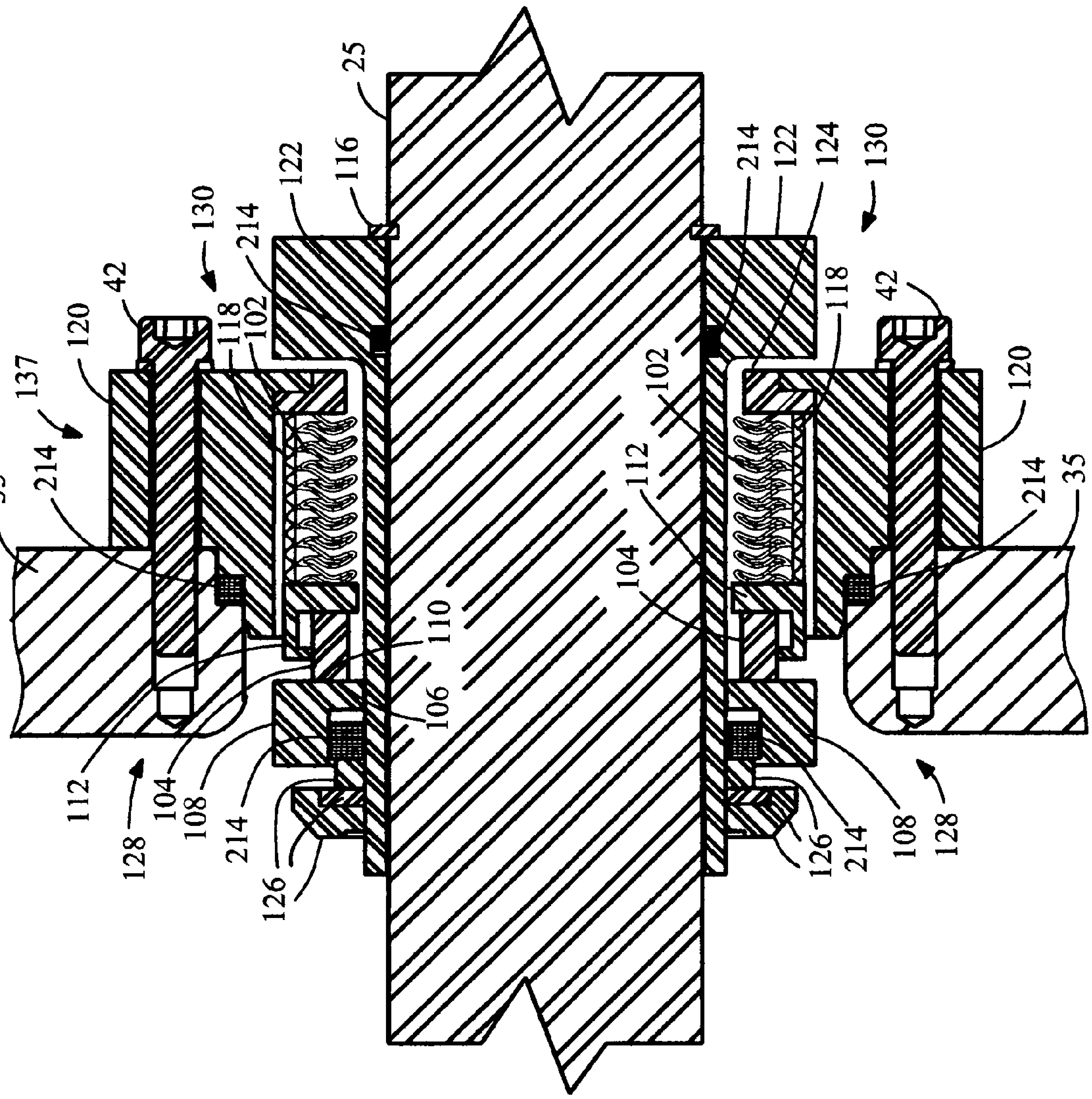
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FIG. 3

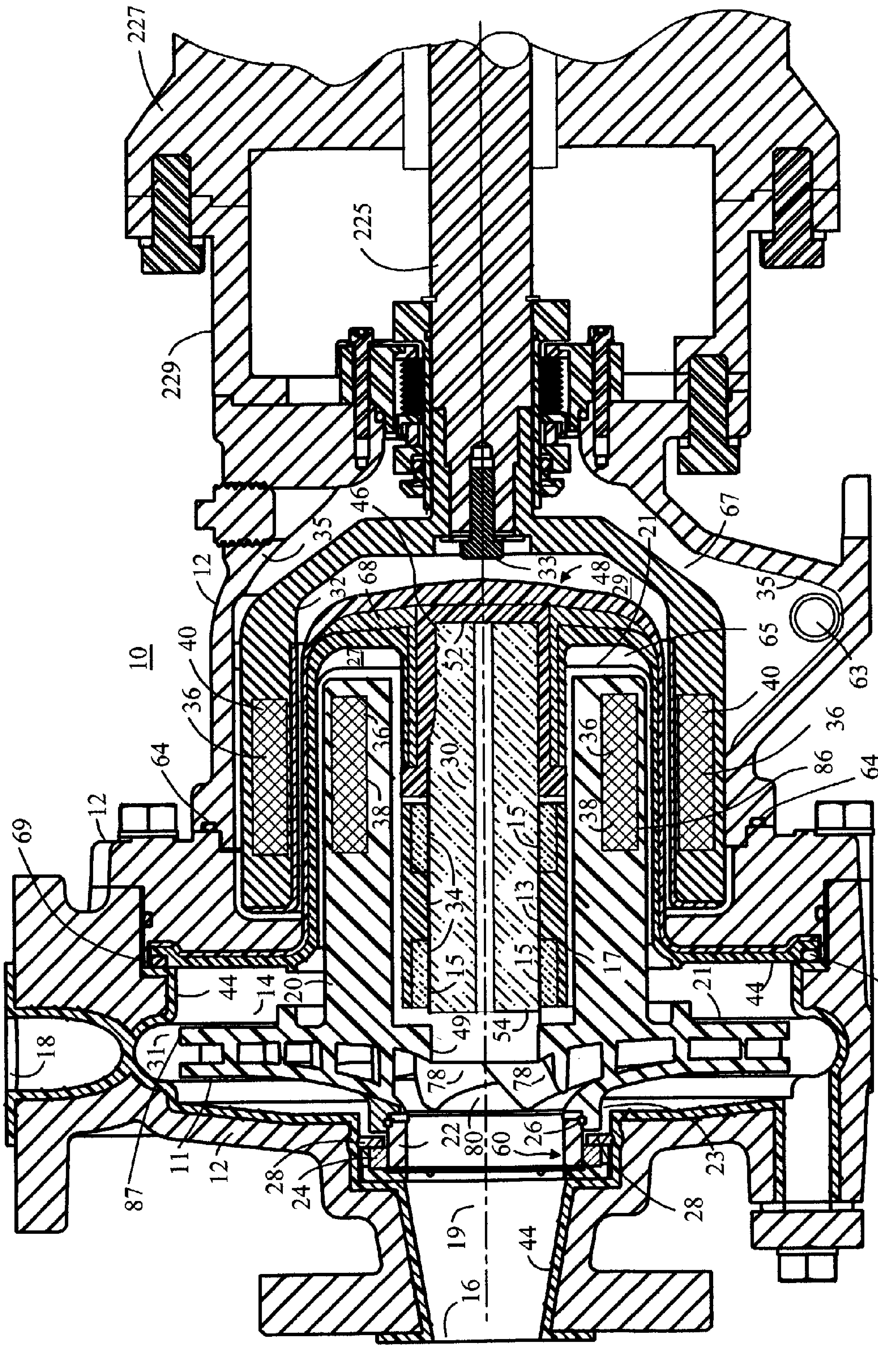
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FIG. 4

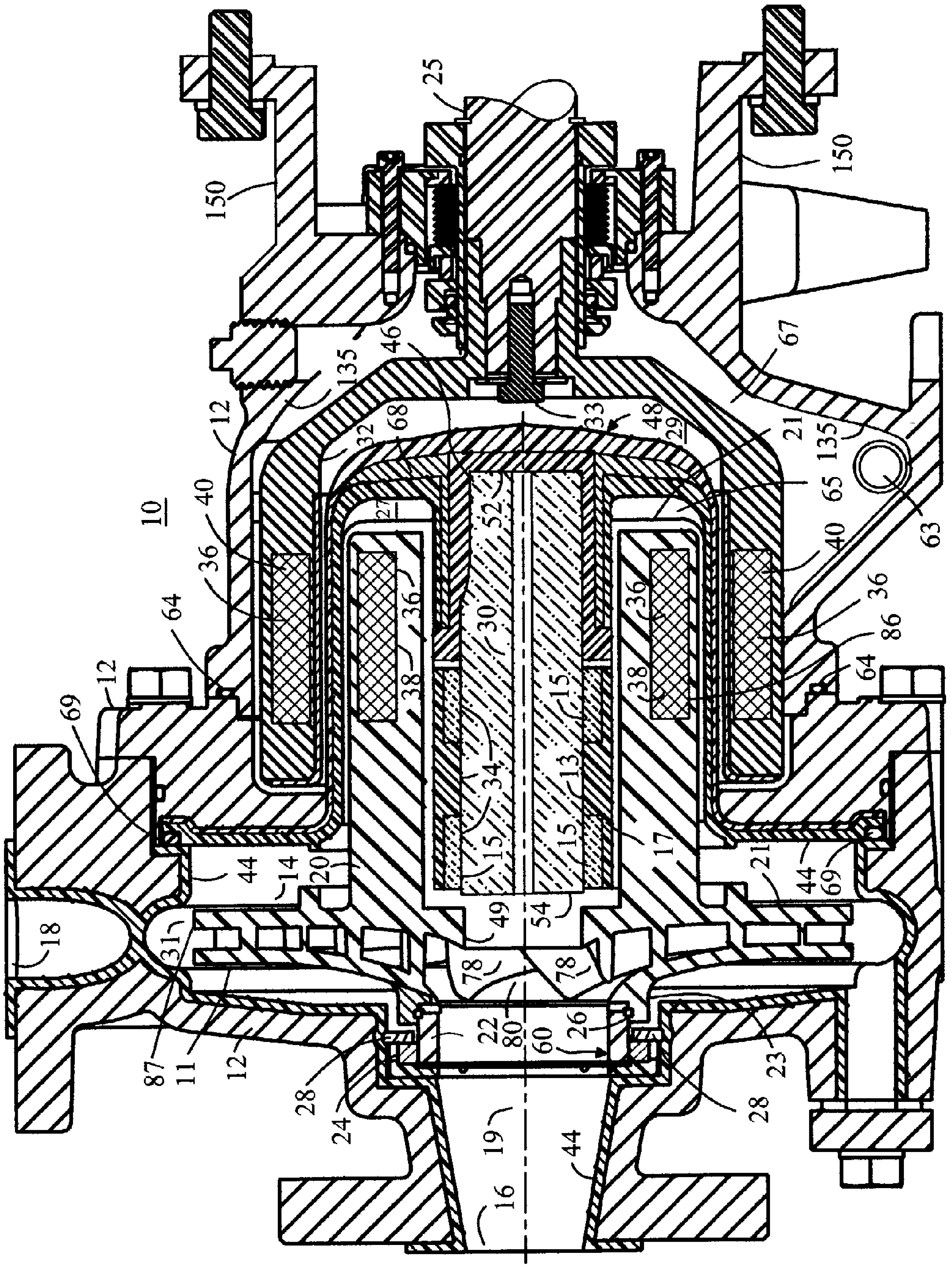
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FIG. 5A

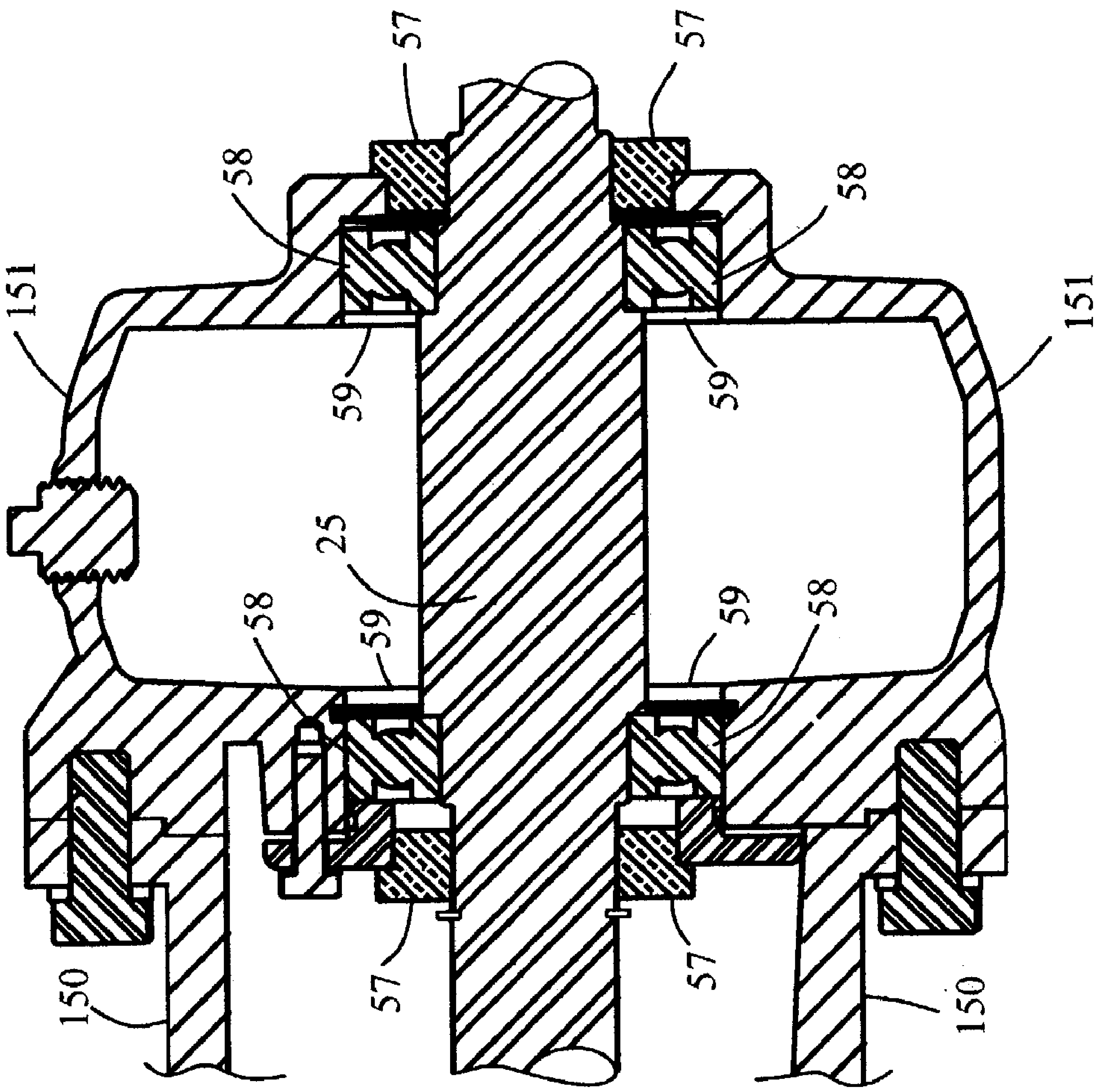

FIG. 5B

SECONDARY CONTAINMENT FOR A MAGNETIC-DRIVE CENTRIFUGAL PUMP

FIELD OF THE INVENTION

This invention relates to secondary containment for a magnetic-drive centrifugal pump.

BACKGROUND

Magnetic-drive centrifugal pumps may be used to pump fluids, such as caustic and hazardous liquids. Instead of shaft seals, a magnetic-drive pump features a pump shaft separated from a drive shaft by a containment shell. The drive shaft is arranged to rotate with one magnetic assembly, which is magnetically coupled to another magnetic assembly. The magnetic assemblies cooperate to apply torque to the pump shaft or an impeller to pump a fluid contained by the containment shell.

Although many magnetic-drive centrifugal pumps are generally reliable, the containment shell may leak or burst from the presence of one or more of the following factors: exposure to excessive heat, exposure to excessive hydraulic pressure, exposure to extreme hydraulic transients, long-term exposure to caustic or corrosive fluids, lack of proper pump maintenance, exposure to excessive particulate matter, and exceeding other operating limitations of the pump. If the pumped fluid is caustic or corrosive, the pumped fluid may erode the interior of the containment shell such that the integrity of the containment shell is degraded over time. If the pump is not properly maintained, excessive radial bearing wear may lead to rubbing or scraping mechanical contact between the impeller and the containment shell that damages the fluid containing capacity of the containment shell. Further, if particles in the pumped fluid accumulate or lodge between the containment shell and the impeller, the containment shell may become scratched, eroded or pitted; and hence, more vulnerable to chemical attack from the pumped fluid.

Leakage of the pumped fluid from an improperly maintained, misused or abused pump may be associated with health and safety risks because the pumped fluid may be hazardous, caustic, flammable, or toxic, for instance. According, even if the probability of a leak of containment shell is relatively low, a need exists for a secondary containment scheme for containing the pumped fluid in the event the containment shell leaks or bursts for any reason.

SUMMARY

A centrifugal pump includes a housing having a housing cavity, an inlet, and an outlet. A pump shaft is located within the housing cavity. A radial bearing coaxially surrounds the pump shaft. The pump shaft and the radial bearing are rotatable with respect to one another. An impeller is positioned to receive a fluid from the inlet and to exhaust the fluid to the outlet. The impeller has a first magnet assembly. A rotor has a second magnet assembly spaced apart from the first magnet assembly. A primary container is interposed between the first magnetic assembly and the second magnetic assembly. The primary container is arranged to contain a pumped fluid. A drive shaft is associated with the rotor for rotating the rotor. A secondary container contains the pumped fluid if the primary container leaks. The secondary container supports a generally dry-running seal (e.g., a non-lubricated seal) associated with the drive shaft. The seal is disposed axially apart from the primary container and has a stationary portion and a rotating portion, where the stationary portion is stationary with respect to the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A and FIG. **1**B are a cross section of a centrifugal magnetic-drive pump with secondary containment in accordance with one embodiment of the invention.

FIG. **2** is an enlarged view of one embodiment of a dry-running seal shown in the circular region **2** in FIG. **1**B.

FIG. **3** shows a cross-section of an alternate embodiment of a dry-running seal that may be incorporated into a centrifugal magnetic-drive pump with secondary containment.

FIG. **4** is a cross section of an alternate embodiment of a centrifugal magnetic-drive pump with secondary containment.

FIG. **5**A and FIG. **5**B are a cross section of another alternate embodiment of a centrifugal magnetic-drive pump with secondary containment.

DETAILED DESCRIPTION

In accordance with one embodiment of the invention, FIG. **1**A and FIG. **1**B, together, illustrate a centrifugal pump **10**. The centrifugal pump **10** includes a housing **12**, a pump shaft **30**, a radial bearing **34**, and an impeller **20**. The housing **12** has a housing cavity **14**, an inlet **16**, and an outlet **18**. The housing **12** may be cast, molded, or otherwise formed by a group of housing sections which can be connected by fasteners, adhesives, or both. The housing cavity **14** is preferably lined with a corrosion-resistant material **44**. A pump shaft **30** is located in the housing cavity **14**. A radial bearing **34** coaxially surrounds the pump shaft **30**. The pump shaft **30** and the radial bearing **34** are rotatable with respect to one another.

An impeller **20** is positioned to receive fluid from the inlet **16** and to exhaust fluid to the outlet **18** during rotation of the impeller **20**. The impeller **20** receives the radial bearing **34**.

FIG. **1**A and FIG. **1**B illustrate one configuration of a magnetic-drive pump **10** in which the pump shaft **30** is cantilevered. The pump shaft **30** has a first end **52** and a second end **54**. In this embodiment, the first end **52** mates with a socket **46** in a primary container **48** or is otherwise mechanically supported by the primary container **48**. The second end **54** is located near a hub **49** of the impeller **20**. The pump shaft **30** of FIG. **1**A is generally hollow or otherwise configured to reduce or eliminate the tendency of hydraulic forces to pull the pump shaft **30** out from the socket **46** in the primary container **48**.

Although the pump shaft **30** is cantilevered, hollow, and stationary as shown in FIG. **1**A, various other shaft configurations are possible and fall within the scope of the invention. In a first alternate configuration, the pump shaft **30** is supported at multiple points, rather than being cantilevered. In a second alternate configuration, the pump shaft **30** is solid, instead of hollow. In a third alternate configuration, the pump shaft **30** is configured to rotate with respect to the housing **12** and one or more radial bearings associated with the pump shaft **30** may be stationary. Any features of the first, second and third alternate configurations may be combined to yield a solid shaft that rotates with respect to the housing **12**, for example.

The pump shaft **30** is preferably composed of a ceramic material or a ceramic composite. In an alternate embodiment, the pump shaft **30** is composed of a stainless steel alloy or another alloy with comparable or superior corrosion-resistance and structural properties. In another alternate embodiment, the pump shaft **30** comprises a metal base coated with a ceramic coating or another hard surface treatment.

The pump **10** may include one or more wear ring assemblies. A front wear ring assembly **60** may be associated with the front side **11** of an impeller **20**. The front wear ring assembly **60** includes a first wear ring **22** and a second wear ring **24**. The first wear ring **22** is associated with the impeller **20** and the second wear ring **24** is associated with the housing **12** of the pump **10**. The second wear ring **24** may be affixed to the housing cavity **14**. The first wear ring **22** may be retained by a corresponding retainer **26** and the second wear ring **24** may be retained by a respective retainer **28**. The front wear ring assembly **60** defines a boundary between a suction chamber **19** and a discharge chamber **31** of the pump **10**.

In one embodiment, one or more wear ring assemblies (e.g., front wear ring assembly **60**) may be composed of ceramic material because ceramic materials tend to hold their tolerances over their lifetime. In addition, smaller tolerances and clearances are possible with ceramic wear rings than for many metals, alloys, polymers, plastics and other materials that are also suitable for wear rings.

In one embodiment, the radial bearing **34** comprises a bushing **15** (e.g., ceramic bushing or carbon bushing) housed in a bearing retainer **13** (e.g., a polymeric bearing retainer). For example, the bushing **15** may be composed of a ceramic material, such as silicon carbide. In an alternative embodiment, the radial bearing **34** may comprise ceramic pads or carbon pads housed in a bearing retainer **13**.

In one configuration, the radial bearing **34** is mated, interlocked, press-fitted, or otherwise mechanically joined with a generally cylindrical region of the impeller hub **49** to preferably define an opening (e.g., a series of spline-like openings) between the impeller hub **49** and the exterior **17** of the radial bearing **34**. The openings between the impeller hub **49** and the exterior **17** support a secondary flow path within the pump **10**, which is secondary to the primary flow path between the inlet **16** and the outlet **18**. In accordance with the secondary flow path, the pumped fluid first travels from the discharge chamber **31** toward a back (to the right in FIG. **1**A) of the pump **10** through a radial gap between the impeller **20** and the primary container **48**. Second, the fluid flows inward toward the pump shaft **30** around the back side **21** of the impeller **20**. Third, the fluid flows toward a front (to the left in FIG. **1**A) of the pump **10** through the opening between the impeller hub **49** and the exterior **17**. Fourth, the fluid flows through the hub **49** and to the suction chamber **19**. The suction chamber **19** is defined by the volume in the interior of the pump **10** around the inlet **16** and the impeller eye **80**.

The impeller **20** preferably comprises a closed impeller, although in other embodiments open impellers, or partially closed impellers may be used. The impeller **20** includes a front side **11** facing the inlet **16** and a back side **21** opposite the front side **11**. For a closed impeller **20** as shown in FIG. **1**A, the front side **11** may be a generally annular surface that terminates in a flange **23**. The back side **21** may include a generally cylindrical portion **86** and a generally annular surface **87** extending radially outward from the cylindrical portion **86**. The impeller **20** includes blades **78** for propelling fluid outward from an impeller eye **80** (e.g., toward the outlet **18**) during rotation of the impeller **20**.

A first magnet assembly **38** is preferably associated with the impeller **20** such that the first magnet assembly **38** and the impeller **20** rotate simultaneously. The first magnet assembly **38** of magnets **36** may be integrated into the impeller **20** as shown in FIG. **1**A. A second magnet assembly **40** is carried by a rotor **32**. A drive motor (not shown) is capable of rotating the drive shaft **25** and the rotor **32**. The second magnet assembly **40** is oriented in magnetic communication with respect to the first magnet assembly **38**. The magnetic assemblies (**38**, **40**) support magnetic coupling between each other to permit the drive shaft **25** to transmit torque to the impeller **20** through the primary container **48**.

The primary container **48** is oriented between the first magnet assembly **38** and the second magnet assembly **40**. The primary container **48** may be sealed to the housing **12** with an elastomeric seal **69** or otherwise to contain the pumped fluid within a wet end **27** of the pump **10** and to isolate the wet end **27** from a dry end **29** of the pump **10** during normal operation of the pump **10**.

The primary container **48** is preferably made of a dielectric, at least in the region where the first magnetic assembly **38** and the second magnetic assembly **40** face one another. For example, the primary container **48** may be composed of one or more layers of a polymer, a plastic, a reinforced-polymer, a reinforced plastic, a plastic composite, a polymer composite, a ceramic, a ceramic composite, a reinforced ceramic or the like. Multiple dielectric layers may be used to add structural strength to the primary container **48** as illustrated in FIG. **1**A.

Although the primary container **48** includes a metallic reinforcement **68** for structured support of the pump shaft **30**, an alternate embodiment may delete the metallic reinforcement **68**. Notwithstanding the foregoing composition of the primary container **48**, alternate embodiments may use metallic fibers to reinforce the dielectric, a metallic containment member instead of a dielectric one, or a single layer of dielectric instead of multiple layers.

The primary container **48** is interposed between the impeller **20** and the rotor **32**. The primary container **48** is arranged to contain a pumped fluid within a primary chamber **65** during normal operation of the pump **10**. The primary chamber **65** is defined by the volume between the impeller **20** and the primary container **48**, which generally contains fluid during normal operation or a normal operational mode of the pump **10**.

The secondary container **35** is positioned generally outward from the primary container **48**. The secondary container **35** supports the dry-running seal **37** and has an aperture for mounting the dry-running seal **37** therein. The dry-running seal **37** is capable of operating in a generally dry or non-lubricated state for continuous, normal operation of the pump **10**. If the primary container **48** leaks, the combination of the secondary container **35** and the dry-running seal **37** is adapted to contain the pumped fluid to prevent leakage or spillage.

In one embodiment, the secondary container **35** represents a generally cylindrical vessel with an open end and an opposite end with an aperture in the opposite end for receiving the dry-running seal **37**. At the open end, the secondary container **35** may have a mating flange for mating with the pump housing **12**. An elastomeric seal **64** or gasket may intervene between the mating flange and the housing **12**. The secondary container **35** may have bores **62** (e.g., threaded bores) for receiving fasteners (e.g., second fasteners **42**) for fastening and mounting the dry-running seal **37**. The secondary container **35** may have a drain plug **55** for inspecting or draining fluid out of the secondary container **35**.

In one embodiment, the secondary container **35** contains a detector or sensor **63** for detecting the presence of a pumped fluid in the secondary container **35**. For example, pumped fluid may be present in the secondary chamber **67** or within the secondary container **35** if the primary container **48** leaks. In one embodiment, the sensor **63** may comprise the combination of an optical source and an optical detector for detecting the presence of a pumped fluid (e.g., an opaque or translucent fluid) or a fluid level within the secondary chamber **67**. In another embodiment, the sensor **63** may comprise an electrical resistance detector for detecting a differential between the electrical resistance provided by air and the electrical resistance provided by the presence of a pumped fluid (e.g., an electrically conductive pumped fluid). In another embodiment, the sensor **63** may comprise the combination of float and electrical switch, a mercury switch, or another detector for detecting the presence of the pumped fluid and providing a switch closure, a contact closure, or an electrical signal in response to the presence of pumped fluid. The sensor output of the sensor **63** may be used to drive an alarm (e.g., an audio or visual alarm) for a user or pump operator, for example. The sensor **63** supports pump maintenance that may be conveniently scheduled without disruption of pumping operations in manufacturing, industrial or commercial applications because the secondary container **35** and the dry-running seal **37** may prevent leakage until pump repair, maintenance or replacement is undertaken.

The pump **10** features a "seal-less" primary containment arrangement and a single-seal secondary containment arrangement for enhanced reliability. The "seal-less" primary containment arrangement comprises the primary container **48**, which is capable of zero emissions or leakage of pumped fluid when functioning properly. Even if the primary container **48** uses an elastomeric seal **69**, gasket, an elastomer, or another sealer to seal the primary container **48** to the housing **12**, the primary containment arrangement may be referred to as "seal-less" in the pump industry because no shaft seal is required for pump shaft **30**. The single seal secondary containment arrangement includes the combination of the dry-running seal **37** and the secondary container **35** to contain any pumped fluid that reaches the interior of the secondary container **35**.

In one embodiment, a bearing frame **51** is associated with the drive shaft **25**. The bearing frame **51** comprises a reservoir **56** for a lubricant, bearings **58** for supporting the drive shaft **25**, and reservoir seals **57** positioned axially outward from the bearings **58** to seal the reservoir **56**. A retention device **59** retains or holds the bearings **58** in proper alignment. The reservoir seals **57** keep the lubricant within the reservoir **56**, while preventing or inhibiting contaminants from entering the reservoir **56** or the bearings **58** (e.g., ball bearings, roller bearings or needle bearings). The bearing frame **51** may be attached to the remainder of the pump **10** via support beams **50** that integrally extend from the bearing frame **51** to the secondary container **35** or a flange thereon. As shown in FIG. **1**B, each support beam **50** is attached to the secondary container **35** via at least one first fastener **43**. In one embodiment, a frame foot **47** may extend from one support beam **50** to support the pump **10** and the bearing frame **51**; a housing foot **45** may extend from a bottom of the housing to support the pump **10**.

The bearing frame **51** does not intervene between the primary container **48** and the dry-running seal **37**. In other words, the dry-running seal **37** is preferably mounted between the bearing frame **51** and the primary container **48**. Accordingly, the dry-running seal **37** and the secondary container **35** protect the reservoir **56** within the bearing frame **51** and any lubricant therein from the ingress of pumped fluid and contamination by the pumped fluid. The foregoing configuration eliminates the need to replace the lubricant within the reservoir **56** upon failure or leakage of the primary container **48** because the lubricant will not generally be contaminated by such leakage. The longevity and reliability of the bearings **58** of the bearing frame **51** is also promoted by preventing contamination of the lubricant.

A motor (not shown) or frame-mounted motor drives the drive shaft **25**. For example, the motor may be connected to an end of the drive shaft **25** in FIG. **1**B. The motor is protected from pumped fluid by the primary container **48** and a combination of the secondary container **35** and the dry-running seal **37**. Accordingly, the windings, magnets, and any internal electrical or electronics associated with the motor are protected from the deleterious effects of the corrosive and caustic pumped fluid by a reliable dual-containment scheme of the primary container **48** and secondary container **35**.

The pump **10** may include an open spatial volume **61** between the secondary container **35** and the bearing frame **51** because the secondary container **35** is connected to the bearing frame **51** by one or more support beams **50** with an open space or open volume (i.e., air) between the support beams **50**. In one embodiment, the open spatial volume **61** is of sufficient dimensions to allow a human worker to introduce a tool or both a tool and a human hand (or part thereof) into the open spatial volume **61** to accomplish one or more of the following: servicing, adjusting, assembling, disassembling, inspecting or maintaining the pump **10**. In one embodiment, the dry-running seal **37** has an adjustment (e.g., a tension setting for adjusting the biasing force applied to the seal faces of the dry-running seal **37**). A worker or another person may readily or conveniently introduce a tool into the open spatial volume **61** to adjust the adjustment or service the seal **37** in order to optimize or otherwise enhance the performance of the dry-running seal **37**, for example.

FIG. **2** shows an enlarged view of the dry-running seal **37** in the circular region **2** of FIG. **1**B. Like reference numbers in FIG. **1**B and FIG. **2** indicate like elements.

In general, the dry-running seal **37** comprises a seal selected from the group consisting of a non-lubricated seal, a dry-running seal, a dry-lubricated seal, and a low-friction seal. The dry-running seal **37** has a first side **128** and a second side **130**. The first side **128** faces the rotor **32** and the primary container **48**. The second side **130** is opposite the first side **128**. The dry-running seal **37** normally operates in a dry-running or non-lubricated mode, wherein the first side **128** of the seal **37** and the second side **130** of the seal **37** are dry or exposed to air during normal operation of the pump **10**. As used herein, normal operation of the pump refers to the state or condition when the primary container **48** is intact and does not leak significantly or, more typically, does not leak at all. The dry-running seal **37** is not lubricated or does not need to be lubricated by any of the pumped fluid, oil, grease, silicone, or another lubricant during a normal operational mode in which the primary container **48** does not leak.

Referring to FIG. **1**A, FIG. **1**B and FIG. **2**, the primary container **48** and the housing cavity **14** generally define the boundaries of the primary chamber **65**. The primary chamber **65** generally contains liquid or pumped fluid during normal operation of the pump **10**. The first side **128** and the secondary container **35** define the boundaries of a secondary chamber **67**. The first side **128** is generally exposed to air and the secondary chamber **67** is generally filled with air during a normal operational mode of the pump **10**. However, the first side **128** may be wet or exposed to the pumped fluid during the failure mode or leakage mode of the pump **10** in which the primary container **48** leaks pumped fluid. Accordingly, the secondary chamber **67** contains pumped fluid during a failure mode of the pump **10** in which the primary container **48** or the primary chamber **65** leaks the pumped fluid. The combination of the secondary container **35** and the dry-running seal **37** prevents the egress of pumped fluid onto the pump exterior, if the primary container **48** leaks.

The dry-running seal **37** has a stationary portion and a rotating portion. The stationary portion is generally stationary with respect to the housing **12**, whereas the rotating portion is rotatable with respect to the housing **12**. The stationary portion is fastened to the secondary container **35** or otherwise secured with respect to the pump **10**. The rotating portion is secured to the drive shaft **25**. The stationary portion interfaces with the rotating portion at an interface, where a rotating seal face **110** meets a stationary seal face **106**. The stationary seal face **106** and the rotating seal face **110** may be biased against each other to substantially inhibit or generally prevent the flow of fluid between any space between the stationary seal face **106** and the rotating seal face **110**. In one embodiment, the faces (**106**, **110**) are constructed with geometric shape, physical material or coating (e.g., polytetrafluoroethylene or another slippery polymer) that requires no lubrication.

The stationary portion comprises a housing adaptor **120** that forms an interface to the secondary container **35**, the housing **12** or a mount associated with the secondary container **35** or housing **12**. In one embodiment, the housing adaptor **120** is fastened to the secondary container **35** by one or more second fasteners **42** (e.g., bolts). The housing adaptor **120** may have a generally annular shape with a recess for receiving an elastomeric seal **114** to form a seal against the passage of fluid between the housing adaptor **120** and an adjoining structure of the pump **10**.

A biasing member **118** has a primary end and a secondary end opposite the primary end. The primary end contacts the housing adaptor **120** or an adjoining ancillary stationary member **124**. The secondary end of the biasing member **118** contacts the stationary member **104** or a holder **112** of the stationary member **104**. The biasing member **118** may comprise a spring, an adjustable spring, an elastomeric member, a torsion member, an adjustable torsion member, an inert gas-charged chamber with a piston, a hydraulically charged chamber with a piston, or another suitable biasing device. The biasing member **118** may provide an axial bias or apply an axial force to the stationary seal member **104**, which is generally annular. For example, the biasing member **118** may provide the axial force via holder **112** which holds the stationary seal member **104** (e.g., a replaceable stationary member).

Bellows **102** may be secured to the ancillary stationary member **124** and the holder **112**, to allow axial movement of the stationary seal member **104** and tension adjustment. An adjuster (e.g., a threaded member, bolt, or screw) for adjusting the tension of the biasing member **118** may facilitate changing the biasing tension of the biasing member **118**. The tension or applied axial force keeps the stationary seal face **106** and the rotating seal face **110** pressed against one another with a degree of force that prevents the flow, passage or leakage of significant fluid between the faces (**106**, **110**), but not so great of a force to cause excessive wear and heat which would degrade seal life of the dry-running seal **37**.

The rotating portion may be secured to the drive shaft **25** to rotate therewith. The rotating portion is secured to the drive shaft **25** by a retainer **116** abutting a collar **122** and an elevation of the drive shaft **25**, a key, or via some other retention means. The rotating portion may include a rotating seal member **108**, the collar **122**, and one or more elastomeric seals **114**. The rotating seal member **108** may comprise a generally annular member that is held axially captive, for example. The collar **122** slips over the drive shaft **25**; one or more elastomeric seals **114** prevent leakage of fluid (a) between the drive shaft **25** and the collar **122** and (b) between the collar **122** and the rotating seal member **108**. The rotating portion may include one or more spacers or ancillary rotating members **126** between the rotating seal member **108** and an end of the collar **122**.

The dry-running seal **37** may provide reduced maintenance and elimination of any lubricant reservoir that a lubricated seal might otherwise require. In one embodiment, the dry-running seal **37** is capable of dry running without the need for product lubrication (i.e., lubrication by the pumped fluid) or any other lubricant, excluding any surface coating or material integrated into the seal faces themselves. Accordingly, the dry-running **37** seal requires no reservoir for holding a lubricant to lubricate the seal and requires no replacement, maintenance, or disposal of the lubricant. Further, the dry-running seal **37** may be resistant to flashing from pumped fluids that contain hydrocarbons or petroleum products.

Although other suitable materials may be used to make the dry-running seal **37**, the following materials may be employed as an illustrative example. The seal faces (**106**, **110**) may be composed of any of the following materials, alone or in combination: ceramic, silicon carbide, a metal, an alloy, a polymer, a polymeric composition, polytetrafluoroethylene, and a slippery polymer. The elastomeric seals **114** may be composed of an elastomer, a fluoroelastomer, synthetic rubber, a rubber composition (e.g., VITON, which is a trademark of E.I. Dupont De Nemours & Company Corporation), or other suitable materials. The bellows **102** may be composed of graphite cloth, flexible graphite webs, a polymer, an elastomer, a fluoroelastomer, or other suitable materials. The holder **112**, collar **122**, ancillary rotating members **126**, ancillary stationary members **124**, and the housing adaptor **120** may be composed of a metal, an alloy, a nickel alloy, a nickel-chromium alloy, a nickel-copper alloy, stainless steel, a corrosion resistant alloy (e.g., HASTELLOY, which is a trademark of Haynes International Corporation) or other suitable metallic, ceramic, or polymeric materials.

FIG. **2** shows a cross section of one embodiment of a dry-running seal **37** that may be incorporated into any of the embodiments of the magnetic-drive centrifugal pump described herein, including embodiments of FIG. **1A** and FIG. **1B**.

The dry-running seal **137** of FIG. **3** is similar to the dry-running **37** seal of FIG. **2**, except the dry-running seal **137** of FIG. **3** includes a thermally tolerant seals **214** (e.g., elastomeric seals or packing rings). The thermally tolerant seals **214** may be composed of a graphite composition or a graphite material, such as GRAFOIL, which is trademark of Union Carbide Corporation, or another material that is capable of sealing during exposure to high thermal stress or high temperatures that exceed a minimum threshold (e.g., above 140 degrees Celsius). Like reference numbers in FIG. **2** and FIG. **3** indicate like elements.

The dry-running seal (**37** or **137**) may be installed into the pump in the following manner, among others. First, the seal (**37** or **137**) may be slid onto the drive shaft **25**. Second, the combination of the drive shaft **25** and the bearing frame **51** is brought axially together with the remainder of the pump **10**. Third, the rotor fastener **33** is tightened to connect the drive shaft **25** to the rotor **32**. Fourth, the seal is slid until it seats against the rotor, a shoulder or another projection on the drive shaft **25**. Fifth, the seal retainer **116** (e.g., a snap-ring) or another holding device is installed in a recess in the drive shaft **25**. Sixth, the first fasteners **43** are tightened to attach the support beam **50** and the bearing frame **51** to the remainder of the pump. Seventh, the second fasteners **42** are tightened to attach the dry-running seal (**37** or **137**) to the pump **10**. Finally, an adjustment, if present, of the seal **37** may be adjusted to a suitable or proper tension between the sealing faces.

The dry-running seal (**37** or **137**) may be removed from the pump **10** in the following manner, among others. Preliminarily, the rotor fastener **33** attaching the drive shaft **25** to the rotor **32** is removed. Second, the second fasteners **42** are loosened to allow the dry-running seal **37** to be removed while connected to the drive shaft **25**. Third, first fasteners **43** are removed to detach a support beam **50** (e.g., a mounting plate and beam) and the bearing frame **51** from the remainder of the pump **10**. Fourth, the drive shaft **25** and the bearing frame **51** are separated axially from the remainder of the pump **10**. Fifth, the seal retainer **116** may be removed. Finally, the seal **37** may be slid off of the drive shaft **25**.

The pump of FIG. **4** is similar to the pump of FIG. **1**A and FIG. **1**B, except the pump of FIG. **4** omits the bearing frame **51** of FIG. **1**B. Further, an adaptor **229** is used to connect a motor casing **227** of the motor (not shown) to the secondary container **35**. The adaptor **229** is connected to the secondary container **35** by one or more fasteners. In turn, the adaptor **229** is attached to the motor casing **227** by one or more fasteners. FIG. **4** represents a closely coupled configuration for a pump in which the motor itself may provide the drive shaft **225** or a mechanical connection to drive shaft **225**. Like reference numbers indicate like elements in FIG. **1**A, FIG. **1**B, and FIG. **4**.

The pump of FIG. **5**A and FIG. **5**B is similar to the pump of FIG. **1**A and FIG. **1**B, except the pump of FIG. **5**A and FIG. **5**B has the following: (a) a modified secondary container **135** that includes an integral support member **150** integrally extending therefrom and (b) a modified bearing frame **151** that excludes the support beams **50**. The pump of FIG. **5**A and FIG. **5**B is similar to the pump of FIG. **1**A and FIG. **1**B, but in the pump of FIG. **5**A and FIG. **5**B the integral support member **150** extends from the secondary container **135**, whereas the pump of FIG. **1**A and FIG. **1**B includes a support beam **50** that extends from the bearing frame **51**. The support member **150** is attached to the bearing frame **151** via at least one fastener. Like reference numbers in FIG. **1**A, FIG. **1**B, FIG. **5**A and FIG. **5**B indicate like elements.

The above detailed description is provided in sufficient detail to allow one of ordinary skill in the art to make and use the invention. The above detailed description describes several embodiments of the invention. The invention may have additional physical variations or additional embodiments that are encompassed within the scope of the claims. For example, the first magnetic assembly **38** may be formed of one or more magnets **36**, because one magnet can be magnetized with a series of different magnetic poles (e.g., multiple north and south poles). Accordingly, any narrow description of the elements in the specification should be used for general guidance rather than to restrict the broader descriptions of the elements in the following claims.

We claim:

1. A magnetic-drive pump comprising an impeller, a rotor separated from the impeller by a primary container, a drive shaft associated with the rotor for rotating the rotor, wherein the improvement comprises:

a bearing associated with the drive shaft and receptive of a lubricant;

the primary container arranged to contain a pumped fluid within the primary container during a normal operational mode of the pump; and

a secondary container for containing the pumped fluid if the primary container leaks, the secondary container supporting a dry-running seal associated with the drive shaft, the secondary container arranged to contain a pumped fluid leaking from the primary container during a failure mode of the pump, the dry-running seal spaced apart from the primary container and comprising a stationary portion and a rotating portion; the rotating portion secured to the drive shaft; the dry-running seal isolated from receiving the lubricant associated with the bearing, the secondary container and the dry-running seal arranged to isolate the bearing from contamination with the pumped fluid upon leakage of the primary container.

2. The magnetic drive pump according to claim **1** wherein the secondary container prevents the egress of pumped fluid onto a pump exterior.

3. The magnetic drive pump according to claim **1** wherein the dry-running seal has a first side facing the primary container and a second side opposite the first side, the first side and the second side being dry or exposed to air during a normal operational mode of the pump.

4. The magnetic drive pump according to claim **1** wherein the dry-running seal has a first side facing the primary container and a second side opposite the first side, the first side being wet or exposed to the pumped fluid during the failure mode of the pump.

5. The magnetic drive pump according to claim **1** wherein the dry-running seal is not lubricated by one of the pumped fluid, oil, grease, silicone, or another lubricant.

6. A centrifugal pump comprising:

a housing having a housing cavity, an inlet, and an outlet;

a pump shaft located within the housing cavity;

a radial bearing coaxially surrounding the pump shaft, the shaft and the radial bearing being rotatable with respect to one another;

an impeller positioned to receive a fluid from the inlet and to exhaust a fluid to the outlet, the impeller having a first magnet assembly;

a rotor having a second magnet assembly spaced apart from the first magnet assembly;

a primary container interposed between the impeller and the rotor, the primary container arranged to contain a pumped fluid within the primary container;

a drive shaft associated with the rotor for rotating the rotor;

a bearing associated with the drive shaft and receptive of a lubricant; and

a secondary container for containing the pumped fluid if the primary container leaks; the secondary container supporting a generally dry-running seal associated with the drive shaft, the generally dry-running seal disposed axially from the primary container and comprising a stationary portion and a rotating portion; the rotating portion secured to the drive shaft; the generally dry-running seal isolated from receiving the lubricant associated with the bearing, the secondary container and the generally dry-running seal arranged to isolate the bearing from contamination with the pumped fluid upon leakage of the primary container.

7. The pump according to claim **6** wherein the primary container comprises a seal-less arrangement; the dry-running seal having no liquid lubricant at an interface of seal faces between the stationary portion and the rotating portion.

8. The pump according to claim 6 wherein the dry-running seal has at least a portion of a first side facing the rotor with the rotor intervening between the dry-running seal and the primary container; the secondary container containing at least a portion of the primary container, at least a portion of the rotor, and at least a portion of the drive shaft.

9. The centrifugal pump according to claim 6 wherein the dry-running seal has a first side and a second side, the first side facing the rotor, the second side opposite the first side, the primary container defining a boundary of a primary chamber, the first side and the secondary container forming a secondary chamber, the first side being exposed to air and the secondary chamber generally filled with air during a normal operational mode of the pump.

10. The centrifugal pump according to claim 9 wherein the secondary chamber is at least partially filled with the pumped fluid during a failure mode of the pump in which the primary container leaks the pumped fluid.

11. The centrifugal pump according to claim 6 wherein the secondary container is associated with a sensor for detecting a presence of the pumped fluid in the secondary container.

12. The centrifugal pump according to claim 6 further comprising a bearing frame associated with the drive shaft, the bearing frame comprising a reservoir for a lubricant, the bearings and an additional bearing for supporting the drive shaft, and reservoir seals positioned axially outward from the bearings to seal the reservoir.

13. The centrifugal pump according to claim 12 wherein a support beam integrally extends from the bearing frame to the secondary container, the support beam attached to the secondary container via at least one first fastener.

14. The centrifugal pump according to claim 12 wherein a support beam integrally extends from the secondary container toward the bearing frame, the support beam attached to the bearing frame via at least one fastener.

15. The centrifugal pump according to claim 6 wherein the dry-running seal normally operates in a dry-running or non-lubricated mode and wherein a first side of the seal and a second side of the seal, opposite the first side, are exposed to air during normal operation of the pump when the primary container is intact.

16. The centrifugal pump according to claim 6 wherein the drive shaft is configured to be driven by one of a closely-coupled motor and a frame-mounted motor.

17. The centrifugal pump according to claim 6 further comprising a motor for driving the drive shaft, the motor being protected from pumped fluid by the primary container and a combination of the secondary container and the dry-running seal.

18. The centrifugal pump according to claim 6 wherein a bearing frame is connected to at least one of the housing and the secondary container via support beams, the support beams defining an open spatial volume for servicing the dry-running seal.

19. The centrifugal pump according to claim 6 wherein the dry-running seal is located between the primary container and the bearing frame to protect the bearing frame from any leakage of the pumped fluid; the bearing frame containing the bearings, an additional bearing, and a reservoir for holding a lubricant for lubrication of the bearings.

20. A centrifugal pump comprising:

a housing having a housing cavity, an inlet, and an outlet;

a pump shaft located within the housing cavity;

a radial bearing coaxially surrounding the pump shaft, the shaft and the radial bearing being rotatable with respect to one another;

an impeller positioned to receive a fluid from the inlet and to exhaust a fluid to the outlet, the impeller having a first magnet assembly;

a rotor having a second magnet assembly spaced apart from the first magnet assembly;

a primary container interposed between the impeller and the rotor, the primary container arranged to contain a pumped fluid within the primary container;

a drive shaft associated with the rotor for rotating the rotor;

a bearing associated with the drive shaft and receptive of a lubricant; and

a secondary container for containing the pumped fluid if the primary container leaks; the secondary container supporting a generally non-lubricated seal associated with the drive shaft, the seal disposed axially from the primary container and comprising a stationary portion and a rotating portion; the rotating portion secured to the drive shaft; the non-lubricated seal isolated from receiving the lubricant associated with the bearing, the secondary container and the non-lubricated seal arranged to isolate the bearing from contamination with the pumped fluid upon leakage of the primary container.

21. The pump according to claim 20 wherein the primary container comprises a seal-less arrangement; the non-lubricated seal having no liquid lubricant at an interface of seal faces between the stationary portion and the rotating portion.

22. The pump according to claim 20 wherein the non-lubricated seal has at least a portion of a first side facing the rotor with the rotor intervening between the non-lubricated seal and the primary container; the secondary container containing at least a portion of the primary container, at least a portion of the rotor, and at least a portion of the drive shaft.

23. The centrifugal pump according to claim 20 wherein the non-lubricated seal has a first side and a second side, the first side facing the rotor, the second side opposite the first side, the primary container defining a boundary of a primary chamber, the first side and the secondary container forming a secondary chamber, the first side being exposed to air and the secondary chamber generally filled with air during a normal operational mode of the pump.

24. The centrifugal pump according to claim 23 wherein the secondary chamber is at least partially filled with the pumped fluid during a failure mode of the pump in which the primary container leaks the pumped fluid.

25. The centrifugal pump according to claim 20 wherein the secondary container is associated with a sensor for detecting a presence of the pumped fluid in the secondary container.

26. The centrifugal pump according to claim 20 wherein the non-lubricated seal normally operates in a generally dry-running mode or non-lubricated mode and wherein a first side of the seal and a second side of the seal, opposite the first side, are exposed to air during normal operation of the pump when the primary container is intact.

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